

# A new model for the travel cost method: the total expenses approach

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## Abstract

This paper discusses the empirical and theoretical underpinnings of the travel cost method (TCM) for estimating nonmarket benefits at an outdoor recreation site. The conventional TCM model is simple to use and provides results that are easy to interpret. However, it does not describe the actual behavior of recreationists as they purchase goods and services for the purpose of making trips to an outdoor recreation site. There is an alternative model that is more congruent with the empirical behavior of recreationists. This model is called the multi-commodity or total expenses TCM model. The total expenses model can also be used to estimate the nonmarket benefits provided by trips to an outdoor recreation site. Moreover, the total expenses model can be derived from the conventional basic postulates of utility maximization. Our purpose in delineating the total expenses model is not to replace the conventional model, but to provide an alternative model. We apply this model to survey data gathered from Trinity River recreationists, and estimate annual nonmarket benefits conferred from recreation activities of US\$406 million. 1998 Published by Elsevier Science Ltd.

**Keywords:** Travel cost method (TCM); Recreation site; Benefits; Consumer surplus

## Software availability

Software name: Limdep™ (Version 7)  
Developer: Econometric Software, Inc.  
Contact address: 43 Maple Avenue,  
Bellport, New York, USA,  
Tel.: + 001-516-286-7049;  
Fax: + 001-516-286-7049.  
First available: 1995  
Hardware required: IBM compatible 386 or  
486 PC running MS-DOS.  
Software required: Limdep™ (Version 7.0 for  
Dos)  
Software cost and  
availability: Cost is about US\$725; can  
be ordered by phone at +  
001-516-286-7049 or by  
mail sent to contact  
address.  
Program size: 2.7–2.9 MB of disk space;

Program language(s): and 8 MB RAM.  
Basic and Fortran  
Software name: S-Plus™ (Windows  
Versions 3.3 and 4.0)  
Developer: MathSoft, Inc.T  
Contact address: 1700 Westlake Avenue N,  
Seattle, Washington, USA,  
Suite 500, Tel.: + 001-  
800-569-0123; E-Mail:  
mktg@stasci.com; Fax: +  
001-206-283-8691.  
First available: 1997 (Windows Version  
4.0)  
Hardware required: Must be 486 or Pentium  
66 MHz machine with  
math coprocessor and  
Windows 95; or running  
Windows NT or Windows  
3.1 × and Win 32s  
Software required: S-Plus™ (Windows  
Version 4.0)  
Software cost and Costs about US\$1350; can

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availability:	be ordered by phone at + 001-800-569-0123 or by mail sent to contact address.
Program size:	40 MB (typical installation) disk space and 32 MB RAM
Program language(s):	S-Plus™, Basic, Fortran

## 1. Introduction

The conventional travel cost method (TCM) model (Clawson and Knetsch, 1966; Hof and King, 1992) is based on the premise that recreationists who visit an outdoor recreation site pay more to access the site as the distance between their residences and the site increases. A key assumption of the model is that the opportunity cost of visiting the site—the travel cost—is an increasing function of the travel distance. On the other hand, the utilities generated by visits to the site are a function of an array of discretionary expenditures. While the purchases of the services of a guide, or supplies can generate important on-site utilities they are not, presumably, a function of the travel distance. Thus, for the conventional model, the purchase of goods that provide on-site utilities does not vary systematically with the travel distance.

There is no loss in analytic generality in assuming that the bundle of goods that generate trip utilities—but are unrelated to travel cost—is identical for all consumers in the conventional TCM model (Hof and King, 1992). The antipodal premise is that the purchase of all trip-related commodities is a stable function of the distance to the site. In this case, the conventional TCM model would have to be reformulated to develop a new conceptual basis for calculating the consumer surplus. The current paper examines the empirical validity of the TCM and develops an alternative model that can be used if the expenditure data suggests that the empirical behavior of recreational users of a site is not consistent with the premises of the conventional TCM.

The consumer surplus is calculated with the conventional micro-data variant TCM model by first estimating a regression relation between the travel cost, which is a simple function of the travel distance, and the number of trips (Douglas and Johnson, 1993). Let  $TC$  be the travel cost and  $s$  be the round-trip distance to the site. The Federal government currently reimburses automobile travel at the rate of US\$0.31 per mile; in this particular case,  $TC = (0.31)s = (0.31)s$ .

Non-travel cost expenses, demographic and socio-economic variables, and trip quality variables (for example, the number of fish caught or ducks bagged) are held at the sample means in estimating the consumer

surplus for trips to the site. The area underneath the curve relating trips to the site and travel cost, above the mean travel cost, is the consumer surplus for the household. Nonmarket benefits provided by the site are equal to the consumer surplus (Douglas and Johnson, 1993). Data on the number of households that use the site and the mean number of trips per household are needed to estimate the aggregate consumer surplus.

## 2. Comparing mathematical models

In the conventional TCM model the agent chooses the optimum number of trips subject to a budget constraint. In the simple case analyzed here in Eqs. (1), (2a), (2b)–(4), the number of trips to the site is a real number and there is only one site. The opportunity costs of trips are out-of-pocket cash expenditures that are a function of the number of trips and the distance to the site.

Let  $U(N, x)$  be the utility function, where  $N \geq 0$  represents the number of trips per unit time,  $Y > 0$  be income,  $s$  the round-trip distance to the site,  $p_s > 0$  be the unit price of travel, and  $x$  be the level of consumption of a (bundle of) market goods. Then  $TC = p_n = [s(p_s)]$  is the travel cost, and  $p_x > 0$  is the price of the market good, and the household maximizes utility subject to the budget constraint. A major focus of the analysis is to demonstrate the usefulness of making a sharp distinction between  $TC$ —a linear function of the distance to the site—and a very disparate definition of travel cost as a certain fraction of total trip expenditures. The utility function is strictly monotonically increasing, strictly concave, bounded from below at  $U(0) = 0$ , continuous, and has continuous first and second derivatives;  $N$  is a real number, not an integer. To find an internal maximum, form the Lagrangean expression

$$L = [U(N, x) + \lambda(Y - p_n N - p_x x)]. \quad (1)$$

The second term in (1) represents the budget constraint; namely, that any nonnegative consumption vector is feasible if expenditures needed to purchase the bundle do not exceed income. The optimum value of  $N$  maximizes  $L$ . Denoting partial derivatives for  $U$  with subscripts, the first-order maximum conditions for  $N$  are stated in Eq. (2a) and Eq. (2b);

$$\begin{aligned} \frac{\partial L}{\partial N} &= U_N(N, x) - \lambda p_n = 0; \text{ thus, } U_N(N, x) \\ &= \lambda p_n. \end{aligned} \quad (2a)$$

$$\begin{aligned} \frac{\partial L}{\partial x} &= U_x(N, x) - \lambda p_x = 0; \text{ thus, } U_x(N, x) \\ &= \lambda p_x. \end{aligned} \quad (2b)$$

A third condition can be derived by differentiation of  $L$  with respect to  $\lambda \geq 0$ , and setting the derivative equal to zero. Namely at an optimum, the budget constraint holds with equality;

$$\frac{\partial L}{\partial \lambda} = (Y - p_N N - p_x x) = 0; Y = p_N N + p_x x. \quad (2c)$$

Let  $N^*$  be the optimum value of  $N$ , and  $[(p_n)^{-1}Y] > N = N^* > 0$  so that the first-order conditions hold at  $(N^*, x^*)$ . Assume that this pair of equations can be inverted to find continuous differentiable single valued functions,  $g_n(p_n, p_x)$  and  $g_x(p_n, p_x)$  that may be regarded as the demand curves for  $N$  and  $x$ . We also assume that

$$\frac{\partial g_n}{\partial p_n} < 0; \quad \frac{\partial g_x}{\partial p_x} < 0. \quad (3)$$

There is little loss in generality in eliminating  $x$  from the utility function by ‘solving’ the budget constraint for  $N$  and substituting the resulting expression in  $U$ ;  $U = H[N, (p_x)^{-1}(Y - p_n N)]$ . The function  $H$  is a numerical representation of a consumer’s utility as a function of  $N$  whose domain of definition is the set of nonnegative vectors  $(N, x)$  for which expenditure equals income. The function  $U$  has as domain of definition the larger subset of nonnegative vectors  $(N, x)$  for which expenditures are less than or equal to income. If  $H$  is strictly concave in  $N$ , the global optimum is unique, and (3) must indeed hold. The function  $H$  is useful in examining corner optima. The graph of  $N$  versus  $TC(= (0.c)s)$  is the conventional TCM micro-variant demand curve, and the area under this curve above the mean travel cost, is the household consumer surplus (see Fig. 1). To convert this value into an aggregate annual value, the number of households using the site in a given year must also be known.

Clearly, all trip related goods generate utilities, hence the consumption of all trip related goods should enter the utility function. However, these goods provide trip related utilities if and only if the number of trips to the site is positive. This last condition might be called a weak complementarity condition. There is another facet of the constraint set in the multi-commodity variant of the TCM, and this constraint element does not occur in the conventional model.

In the previous model, the household ‘purchased’ trips to the site even though trips to the site are not sold in competitive market. In a multi-commodity setting, it is useful to explicitly model the manufacture of trips by the household. Consider a rural family with 14 members which operates a farm sales equipment store. This family owns a 40-acre plot of land that it uses to raise vegetables for direct consumption when the family has 14 people eating meals. The children grow up and leave the

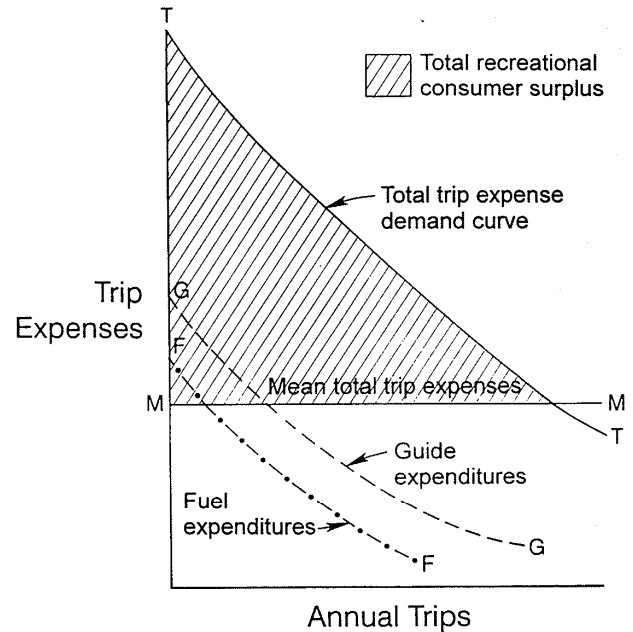


Fig. 1. FF and GG represent trips versus fuel expenditures and guide expenditures curves for the trip demand curve TT.

household. Eventually the family household shrinks to a pair of parents, who operate and sell the produce from the 40-acre plot of land so as to maximize net revenues. Clearly, the owner-operators of this truck garden face a production function for raising vegetables regardless of whether they sell the output in the market or consume the output at the dinner table. When the family grows vegetables for direct consumption it is formally correct to introduce the production function into an augmented utility function.

We introduce the production function into an augmented utility function in our analysis in order to provide a formal version of the conventional TCM model. The utility function is now  $U(N; x_1, \dots, x_m; z) = U(N; \bar{x}; z)$  where  $p_z$  and  $z$  are the price and the quantity of the (bundle of) other market good(s);

$$U(N; x_1, \dots, x_m; 0) \geq 0, \quad U(0; \bar{x}; 0) = 0. \quad (4)$$

The utility function passes through the origin, and  $U(0; \bar{0}; 0) = 0$ ; it is bounded from below by 0, and is unbounded from above. It is strictly concave, strictly monotonically increasing for  $N > 0$ , and has continuous first- and second-order partial derivatives.

The budget constraint is

$$Y \geq \sum_{i=1}^m p_i x_i + p_z z; \quad Y > 0. \quad (5)$$

Because  $Y > 0$ , the set of nonnegative vectors  $(\bar{x}, z)$  that satisfy (5) is a non-empty, compact (e.g., closed and

bounded), convex set. The number of trips are the output of the production process. In this model all effects of changes in the distance from the site are captured by changes in the cost of the trips. From (4), the consumer maximizes  $U[G(\bar{x}), \bar{x}, z]$ , for  $\bar{0} \leq \bar{x}$ ,  $0 \leq N \leq G(\bar{x})$ , and  $0 \leq z$ . The production function  $G(\bar{x})$  is strictly monotonically increasing, strictly concave, has continuous first and second partial derivatives, is unbounded from above, and  $G(0, \bar{0}, 0) = 0$ .

Marginal utility for all goods are positive; thus,

$$\frac{\partial U}{\partial N} = U_n > 0, \quad \frac{\partial U}{\partial x_i} = U_i > 0, \quad i = 1, \dots, m; \quad (6a)$$

and

$$\frac{\partial G}{\partial x_i} = G_i > 0, \quad i = 1, \dots, m. \quad (6b)$$

Let  $U_{NN}$ ,  $U_{ii}$ , and  $G_{ii}$  designate second-order partial derivatives, and  $U_{ij}$  and  $G_{ij}$  designate second-order cross-partial derivatives;

$$U_{NN} < 0, \quad U_{ii} < 0, \quad G_{ii} < 0, \quad i = 1, \dots, m. \quad (6c)$$

### 3. The analysis of a multi-commodity model

The model is reformulated in this section so that the conventional theory of consumer choice can be used as a guide to the derivation of the economic effects. Assume that the augmented utility function  $U[G(\bar{x}), \bar{x}; z]$  is monotonically increasing and strictly concave in  $\bar{x}$ . The model can be simplified by introducing two new variables into the model, the unit price of trips to the site  $p_s > 0$ , and the price of trips to the site  $p_N = [s(p_s)]$ ; in this manner we can deal with changes in the price of trips to the site. The Lagrangean for the maximization problem is now

$$L = U[G(\bar{x}), \bar{x}, z] + \lambda[Y - \sum_{i=1}^m p_i x_i - p_z z - s(p_s \cdot G(\bar{x}))]. \quad (7)$$

We further simplify the model by dropping  $p_z$  and  $z$  from the model. There is at least one good  $x_i$  that produces trip related utilities for which  $G_i = 0$ , and one good  $x_j$  that produces non-trip related utilities (and therefore  $G_j = 0$ ) in the set of  $m$  goods. Hence, if  $G_i = 0$  for  $x_i$ , one can regard  $x_i$  as a good that produces trip or non-trip related utilities. The weak complementarity condition does not hold for the (set of) good(s) that generates non-trip utilities; this (bundle of) good(s) generates utilities even if no trips occur.

The first-order maximization conditions for an internal maximum are

$$\frac{\partial L}{\partial x_i} = G_i(U_N) + U_i - \lambda p_i - \lambda(s p_s) G_i = 0 \quad (8)$$

for  $i = 1, \dots, m$ . The derivative of  $L$  with respect to  $\lambda$  must also equal zero; at a constrained maximum, the budget constraint is satisfied with equality. Recall that the set of nonnegative vectors that satisfy the weak inequality for the budget constraint is non-empty, compact, and convex. Every continuous function on a compact set attains its maximum, hence there is at least one feasible nonnegative consumption vector that maximizes utility relative to other feasible vectors. Let  $h_i(\bar{x})$  be the sum of the terms in (8) that contain the decision variables;

$$h_i(\bar{x}) = U_N(G_i) + U_i - \lambda p_s(s G_i). \quad (9)$$

The price, distance, and income effects for the demand equations can be developed by finding the total derivatives for  $h_i(\bar{x})$  with respect to the decision variables, lambda, the prices, distance, and income.

The total derivatives are

$$\left[ \frac{\partial h_i}{\partial x_i} \right] dx_i + \sum_{j \neq i}^m \left[ \frac{\partial h_i}{\partial x_j} \right] dx_j - [p_i + p_s(s G_i)] d\lambda = \lambda dp_i + (\lambda G_i) p_s ds \quad (10)$$

for each  $h_i(\bar{x})$ ,  $i = 1, \dots, m$ . The border is

$$- \sum_{i=1}^m p_i dx_i - s p_s \sum_{i=1}^m G_i dx_i = -dY + \sum_{i=1}^m x_i dp_i + p_s G ds. \quad (11)$$

Differentiating the right-hand side of Eq. (9),

$$\frac{\partial h_i}{\partial x_i} = U_N(G_{ii}) + U_{NN}(G_i)^2 + 2U_{Ni}(G_i) + U_{ii} - \lambda(s p_s) G_{ii} \quad (12)$$

and

$$\frac{\partial h_i}{\partial x_j} = U_N(G_{ij}) + U_{NN}(G_i G_j) + U_{iN}(G_j) + U_{Nj}(G_i) + U_{ij} - \lambda(s p_s) G_{ij}. \quad (13)$$

The next step is to solve for the derivatives with respect to distance for the system of equalities formed by Eqs. (8)–(13) with the aid of Cramer's rule



The area under the curve of the graph of the number of trips versus total trip expenditures above the mean travel expense is the consumer surplus.

The consumer surplus estimate generated by the trips versus total expenses relation is for the total recreational experience generated by trips to the site. It is clearly a broader concept than the consumer surplus generated by the conventional TCM model. By the strict concavity of the augmented utility function, there is a unique number of trips demanded for any given distance to the site. Each distance from the site also corresponds to a unique quantity demanded for each of the trip related items. Thus, the total expenses demand curve can be decomposed into a set of expenditure curves for individual trips related items (see Fig. 1). In Fig. 1 each point on the fuel expenditure curve FF corresponds to an amount of money (per unit time) spent on fuel. The vertical sum of the expenditure curves is the total expenses demand curve (see Fig. 1). The consumer surplus for items such as fuel or guides can be defined as the area underneath the graph of the relevant expenditure curve above the horizontal mean total expenses line (Fig. 1). This definition of the individual item consumer surplus implies that the sum of the consumer surpluses for the individual items is equal to the total consumer surplus.

The definition of the consumer surpluses for the individual items suggests a method for converting the total expenses consumer surplus into a value that is comparable with the conventional TCM consumer surplus. The ratio of the area underneath the item expenditure curve to the area underneath the trips versus total expenses demand curve is approximately equal to the fraction of expenditures spent on the commodity in question for any point value of total expenses (Fig. 1). The sum of the areas under the individual item demand curves must be exactly equal to the corresponding area underneath the total expenses demand curve. If the demand curve for some item is exactly parallel to the trips demand curve,

$$0 < r_i = \frac{(CS_i)}{(CS)} = \frac{E_i}{E} < 1, \quad (20)$$

where  $i$  indexes the  $i$ th trip related good,  $E_i$  represent expenditures on the  $i$ th category,  $E$  is total trip expenses,  $(CS_i)$  is the consumer surplus from the item demand for the  $i$ th trip item, and  $(CS)$  is the total recreation experience consumer surplus. The simplest way to calculate the TCM equivalent consumer surplus from the total expenses demand curve is to define a synthetic good called 'travel cost' whose demand curve is, by definition, parallel to the total expenses demand curve. From Eq. (20), the ratio of expenditures for travel cost to the total trip expenses multiplied by  $(CS)$  provides  $(CS_{tc})$ , the travel cost consumer surplus.

## 5. An empirical example

In Douglas and Taylor (1998a), we used the TCM to estimate current nonmarket benefits from recreational visits to California's Trinity River. The data was gathered from a survey that we administered in the winter of 1993–1994 to Trinity River recreationists. The Trinity River is the largest tributary of the Klamath River (Fig. 2). At one time, the only Pacific Coast river systems in the lower 48 states that produced more anadromous fish than the Klamath–Trinity system were the Columbia and Sacramento River systems (Pacific Fishery Management Council, 1995). In 1963, the Trinity Division of the Central Valley project, including Trinity and Lewiston dams, was completed (U.S. Bureau of Reclamation, 1980; see Fig. 2). From 1964 through 1980 about 90% of the mean annual 1.2 million acre-feet of the Trinity River outflow from Trinity Dam was diverted to the nearby Sacramento River and the Central Valley Project for hydropower, agricultural, and other uses (U.S. Bureau of Reclamation, 1980). Damming the Trinity River also resulted in a substantial loss of upstream spawning habitat, and anadromous fish stocks declined 90% after 1964 (Hubbell, 1973). Thus the social cost of moving more water down the Trinity River includes both foregone hydropower and irrigation water. The economic benefits are nonmarket recreational and off-site (existence or preservation) benefits generated by improved streamflows and more viable and larger anadromous fish runs.

During the winter of 1993–1994 we mailed out 2044 Trinity River user surveys<sup>1</sup> to gather data needed to estimate the nonmarket benefits of improved Trinity River streamflows and fish runs to Trinity River recreationists. The Planning Department of Trinity County mailed out 2717 surveys to a random selection of Pacific Coast households to estimate the nonmarket benefits of improved streamflows to Pacific Coast residents—this survey was called the household survey. The household survey and the user survey gathered information on the willingness-to-pay for improved streamflows as well as demographic characteristics of the respondents. The household survey provided information on the number of Trinity River recreationists.

The effective response rate for the mail-out user survey—most of the 1003 user responses for the TCM analysis were mail-back responses—was 70%; address unknowns were deleted in calculating response rates (Douglas and Taylor, 1998b). The user survey data base includes 1349 responses that could be used to make contingent value method (CVM) streamflow benefits estimates. Only 1003 responses included all of the information needed for the TCM model including the number

<sup>1</sup> The user survey was approved by the Office of Management and Budget (OMB approval number 1018–0085).

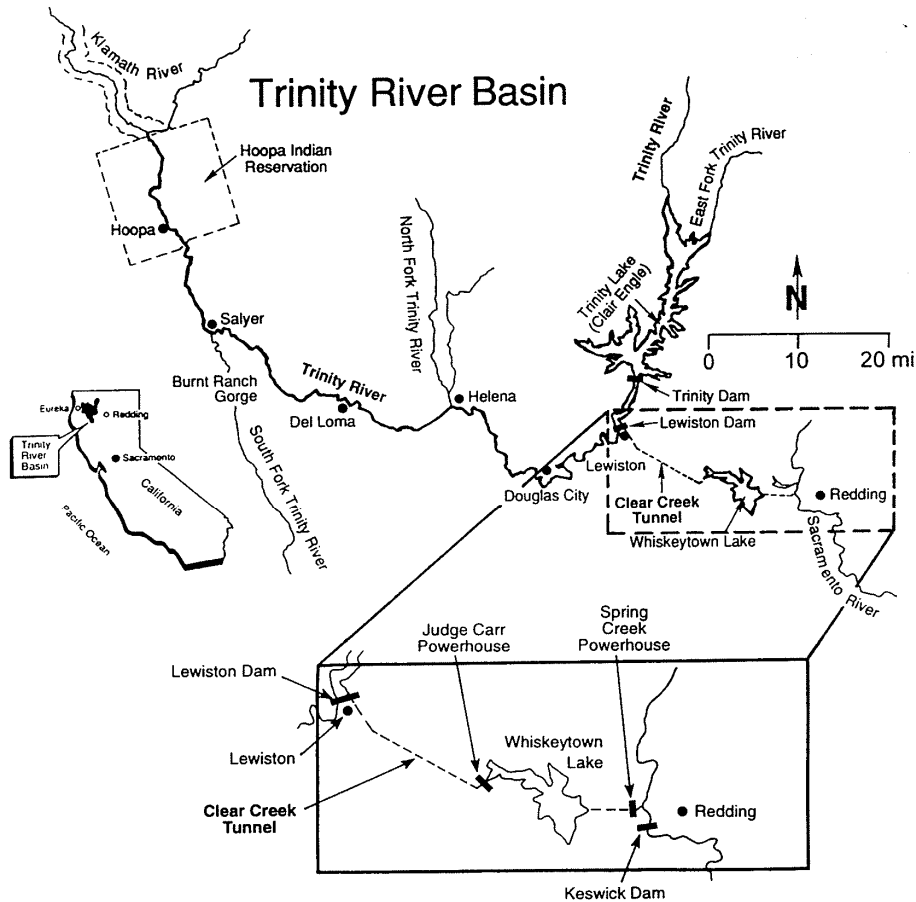


Fig. 2. Map of the Trinity River Basin with the route of the diverted water shown in detail.

of trips to the site, the one-way distance traveled, and per trip recreation expenditures. Also, 412 respondents did not report a full set of expense items so that one of the expense values had to be imputed. The five variable cost trips categories included in the total trips expenses category include food, fuel, guides, lodging, and supplies. We imputed values to missing total expenses data by equating the value of the missing item to zero. Only 591 of the 1003 cases reported a complete set of expenses. This subset is called the 'full-expenses data set' and was used to estimate the model (e.g., the values for the parameters in (21) were determined from this data set). The 412 observations with a missing expense item is entitled the 'incomplete-expenses data set'. The incomplete data set was used to make out-of-sample (conventional terminology) predictions of the dependent variable and correlative goodness-of-fit sample statistics (Creel and Loomis, 1990).

Eq. (21) works well with the Trinity River data set;

$$y = b + \frac{b_c}{x_c} + \frac{b_d}{x_d} + \epsilon; \epsilon \sim N(0, \sigma^2), \quad (21)$$

where  $y$  is the number of trips per annum,  $x_c$  is average

total variable trips expenses,  $x_d$  is one-way distance to the site,  $b_c > 0$ , and  $b_d > 0$ , are the coefficients of the explanatory variables,  $b$  is a constant, and the error term is a random normal variable. If (21) is estimated by ordinary least squares (OLS)—the OLS version of (21) was estimated with Limdep™—new variables are created that are the inverse of travel expenses and the inverse of travel distance. A dollar was added to expenses to prevent the inverse from being infinite if expenses were equal to zero; for the same reason 0.25 miles were added to the distance. We also estimated a variant of (21) called PII with a random Poisson distributed error term with a maximum likelihood estimator and an S-Plus™ program. Let  $e^x = (\exp x)$ ; we call the model in (22) the conventional Poisson model because packages such as Limdep™ estimate the canonical form

$$y = \exp[c + b_1x_1 + \dots + b_nx_n] \quad (22)$$

with an error term that is a random, Poisson variable. For PII, we estimated

$$y = [c + b_cx_1 + \dots + b_nx_n] + \epsilon. \quad (23)$$

The error term in (23) is a Poisson random variable.

The OLS and PII versions of (21) produced good fits, and total recreational consumer surplus estimates of US\$4.064 billion (Poisson error model) and US\$4.113 billion per annum (OLS model). The conventional TCM benefits estimates were US\$406.351 million per annum for the Poisson error model and US\$411.251 million per annum for the OLS model. Annual benefits were more than 20 times the annual social cost of streamflows at the flow level (340 000 acre-feet per annum) at which the trips occurred. Benefits at the flow level at which trips occurred were 8 times the social costs of providing the highest flow (840 000 acre-feet per annum) listed in the survey CVM scenarios. The coefficient of the travel expenses variable—regardless of whether expenses were broadly or narrowly defined—was always negative, and the *t*-value of the coefficient indicated high explanatory power for this variable. However, as the number of expenditure categories used to define variable trip expenditures increased, the fit of the model improved notably.

Table 1 (produced by Lotus 1-2-3™) illustrates the relation between trips to the site for the 12 month period preceding the mail-out of the users survey and distance traveled for Trinity River recreationists. Table 1 demonstrates an almost monotonically decreasing relation between distance traveled and the number of trips. However, the data in Table 1 are highly aggregated, and the observations that enter the regression model are disaggregated. Hence, the use of more precise indicators of goodness-of-fit is helpful in reaching an informed judgment about the strength of the empirical relation linking trips and travel expenses. One other feature of Table 1 that should be noted is that the provenance of the six distance groups in Table 1 is a regional input-output model by Douglas and Draper (1997). This model used survey data to estimate the employment impacts of Trinity River recreation trip expenditures.

The arithmetic underlying the calculation of the conventional TCM benefits estimates is presented briefly. The mean trip expenses for all households in the complete expenses data set was US\$553.8, the mean number of trips per household was 5.9812, the mean round-trip travel distance was 551.4 miles, and 711 585 households made Trinity River recreation trips in 1993–1994. Mean fuel costs were US\$72.99;  $r = (\text{US\$72.99}/\text{US\$553.8}) =$

0.1318. Hence, a lower bound for 'travel cost' could be based on the assumption that most of the fuel purchased is used in traveling to the site. Thus,  $\alpha = 0.1$  was chosen as a plausible lower bound ratio of travel cost to total trip expenses and used to convert total benefits estimates into TCM consumer surplus estimates.

The problem with  $\alpha$  is that it provides lower bound estimates. The US Federal Government currently reimburses travel cost by automobile at the rate of US\$0.31 per mile. This fact could also be used to calculate a value for the travel cost as  $\beta = [(551.4)(\text{US\$0.31})/(\text{US\$553.8})] = 0.3087$ . Creel and Loomis (1990) use a travel cost value of US\$0.22 per mile. An adjustment of the Creel and Loomis (1990) cost per mile value for a 3% annual inflation rate results in a conversion factor of  $\lambda = 0.2616$ .

Table 2, in concert with Table 3, illustrates an empirical weakness of the conventional TCM model. The cell values in Table 2 are the 1993 mean per trip dollar expenditures for trips taken in the last 12 months for each of these categories that are used almost entirely at the site. In Table 3, the individual cell values are the 1993 median dollar per trip expenditures for trips taken in the last 12 months for each of five expenditure categories.

The data in Tables 2 and 3 have been smoothed by imputing the mean value for the cell for missing observations. The regression models were estimated on cases for which there were no missing expenditure data. The out-of-sample predictions were made on a 412 case data subset for which missing expense items were imputed a value of zero; this procedure does not 'smooth' the data. However, on average, fewer than 10% of the observations in each cell were imputed. Therefore, the smoothing of the data should not affect the expenditures versus distance relation. Table 2 exhibits a roughly monotonically increasing relation between distance and expenditures. There are some irregularities in this relation, the most notable being that mean expenditures for recreationists who reside in the 0–30 mile distance travel zone are greater for every category than for those Trinity River users who live in the 31–60 mile zone. However, the anomalies in Table 2 are virtually eliminated in Table 3. Median expenditures are relatively insensitive to large outlays by a relatively few individuals.

Users who live furthest from the site spend an average of 3.995 times as much on fuel as do those who live closest to the site. The comparative values for food and lodging are 6.481 and 4.691. The two 'non-travel cost categories' are supplies and guides. Supply expenditures increase by a factor of 3.694 as distance ranges from the lowest to the highest category, and the corresponding value for guides is 5.325. Median supply expenditures increase by a factor of 20 in Table 3 as the maximum distance from the site increases from 30 miles to more

Table 1

One-way travel distance to the Trinity River recreation site versus the average annual trips for 1214 respondents for six distance categories

One-way distance in miles	Average number of trips
0–30	37.2
31–60	7.6
61–120	7.7
121–240	2.9
241–480	2.4
> 480	1.6



Table 2

One-way travel distance in miles to the Trinity River recreation site versus mean expenditures in 1993 dollars for five variable trip expenditure categories for 1003 recreationists (S-Plus™ program output)

Distance	Fuel	Food	Supplies	Guides	Lodging
0–30	37.39	42.17	28.36	47.43	56.45
31–60	21.24	35.57	20.06	39.63	22.23
61–120	36.81	63.17	25.43	26.83	48.06
121–140	60.40	131.37	62.78	157.04	171.08
241–480	74.96	153.51	76.76	127.14	195.02
> 480	149.38	273.31	104.76	252.57	264.82

Table 3

One-way travel distance in miles to the Trinity River recreation site versus median expenditures for five variable trip expenditure categories for 1003 recreationists (S-Plus™ program output)

Distance	Fuel	Food	Supplies	Guides	Lodging
0–30	12.5	22.5	5	0	0
31–60	20	20	10	0	0
61–120	30	40	10	0	0
121–140	50	100	50	100	100
241–480	60	115	50	100	125
> 480	100	200	100	190	200

than 480 miles. Thus, outlays for the non-travel cost items are highly responsive to changes in distance.

Table 4 supplements the information presented in Table 1 by providing quantitative measures of the goodness-of-fit of two variants of Eq. (21) (OLS and PII) in Table 4. Statistics for a third model, the linear OLS model in which the expenses and distance variables are not inverted, are presented in another column in Table 4. The linear OLS model is the textbook version of the conventional TCM model. Hence, it is included in Table 3 despite the fact that it does not provide a good fit for the Trinity River data set. Note that a finite travel cost (distance) cuts off all trips to the site for this model.

The linear OLS model is particularly convenient to use for the purpose of contrasting the disparate consumer

surplus estimates produced with the conventional TCM model and the total expenses model. A linear homogenous transformation of one independent variable does not change the  $R^2$ ,  $F$ -statistic, or the  $t$ -values of the estimated coefficients in the linear OLS model with randomly normally distributed errors. To calculate the conventional consumer surplus, the distance variable must be replaced by a variable which represents the travel cost of the roundtrip distance to the site. The new variable is called TCM(1) if the travel cost is US\$0.1004 per mile, and TCM(2) if the travel cost is US\$0.2627 per mile. The use of TCM(1) in conjunction with the total expenses model generates the annual consumer surplus of US\$285.47 million dollars per annum listed in Table 4. The per mile travel cost value for TCM(2) generates an

Table 4

Coefficients,  $t$ -values (in parenthesis),  $R^2$ , and benefits estimates for two variants of Eq. (21)—OLS (Limdep™ output) and PII (S-Plus™ output)—and the linear OLS model (Limdep™ output)

Parameter or statistic	Linear OLS	OLS	PII
Constant	8.123 (5.903)	2.20571 (2.828)	2.4586 (3.354)
$b_c$	– 0.003721 (– 2.213)	68.798 (10.883)	71.018 (11.103)
$b_d$	– 0.003889 (– 1.584)	14.878 (10.778)	9.8183 (7.029)
In-sample $R^2$	0.0157	0.4024	0.3943
Trips	2945	2945	2945
Pred. trips	2945	2945	2945
Out-of-sample $R^2$	0.0329	0.3223	0.3724
Out-of-sample trips	1300	1300	1300
Pred. trips	1940.8	1022.3	1170
Percent error	+ 49.3%	– 21.4%	– 10.0%
Annual benefits	US\$285.47 million	US\$411.251 million	US\$406.351 million

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